

## Claims

- [c1] 1. A phosphor composition for a backlight source of a liquid crystal display ("LCD"), said phosphor composition comprising at least a phosphor emitting blue light, at least a phosphor emitting green light, and at least a phosphor emitting red light; wherein said at least a phosphor emitting blue light is selected from the group consisting of  $(\text{Sr,Ca,Ba,Mg})_{10}(\text{PO}_4)_6(\text{F,Cl,Br,OH})\text{:Eu}^{2+}$ ;  $(\text{Ba,Sr,Ca})\text{MgAl}_{10}\text{O}_{17}\text{:Eu}^{2+}$ ;  $(\text{Sr,Ca})_{10}(\text{PO}_4)_6 \cdot n\text{B}_2\text{O}_3\text{:Eu}^{2+}$ , wherein  $0 < n < 1$ ;  $2\text{SrO} \cdot 0.84\text{P}_2\text{O}_5 \cdot 0.16\text{B}_2\text{O}_3\text{:Eu}^{2+}$ ;  $\text{Sr}_2\text{Si}_3\text{O}_8 \cdot 2\text{SrCl}_2\text{:Eu}^{2+}$ ;  $\text{Ba}_3\text{MgSi}_2\text{O}_8\text{:Eu}^{2+}$ ;  $\text{Sr}_4\text{Al}_{14}\text{O}_{25}\text{:Eu}^{2+}$ ;  $\text{BaAl}_8\text{O}_{13}\text{:Eu}^{2+}$ ; and mixtures thereof; said at least a phosphor emitting green light is selected from the group consisting of  $(\text{Ba,Sr,Ca})\text{MgAl}_{10}\text{O}_{17}\text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{Ba,Sr,Ca})\text{Al}_2\text{O}_4\text{:Eu}^{2+}$ ;  $(\text{Y,Gd,Lu,Sc,Lu})\text{BO}_3\text{:Ce}^{3+}, \text{Tb}^{3+}$ ;  $(\text{Ba,Sr,Ca})_2\text{SiO}_4\text{:Eu}^{2+}$ ;  $(\text{Ba,Sr,Ca})_2(\text{Mg,Zn})\text{Si}_2\text{O}_7\text{:Eu}^{2+}$ ;  $(\text{Sr,Ca,Ba})(\text{Al,Ga,In})_2\text{S}_4\text{:Eu}^{2+}$ ;  $(\text{Y,Gd,Tb,Lu,Sm,Pr,Lu})_x(\text{Al,Ga,In})_y\text{O}_{12}\text{:Ce}^{3+}$ , wherein  $x$  is in the range from about 2.8 to and including 3, and  $y$  is in the range from about 4.9 to about 5.1;  $(\text{Sr,Ca,Ba,Mg,Zn})_2\text{P}_2\text{O}_7\text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{Ca,Sr,Ba,Mg})_{10}(\text{PO}_4)_6\text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{F,Cl,Br,OH})\text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{Ca,Sr,Ba})_8(\text{Mg,Zn})(\text{SiO}_4)_4(\text{Cl,F})_2\text{:Eu}^{2+}, \text{Mn}^{2+}$ ; and mixtures thereof; and said at least a phosphor emitting red light is selected from the group consisting of  $(\text{Gd,Y,Lu,Lu})_2\text{O}_3\text{:Eu}^{3+}, \text{Bi}^{3+}$ ;  $(\text{Gd,Y,Lu,Lu})_2\text{O}_3\text{S}\text{:Eu}^{3+}, \text{Bi}^{3+}$ ;  $(\text{Gd,Y,Lu,Lu})\text{VO}_4\text{:Eu}^{3+}, \text{Bi}^{3+}$ ;  $\text{SrS}\text{:Eu}^{2+}$ ;  $\text{SrY}_2\text{S}_4\text{:Eu}^{2+}$ ;  $\text{CaLa}_2\text{S}_4\text{:Ce}^{3+}$ ;  $(\text{Ca,Sr})\text{S}\text{:Eu}^{2+}$ ;  $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2\text{:Mn}^{2+}$ ;  $(\text{Ba,Sr,Ca})\text{MgP}_2\text{O}_7\text{:Eu}^{2+}, \text{Mn}^{2+}$ ; and mixtures thereof.
- [c2] 2. The phosphor composition according to claim 1, wherein said phosphor composition absorbs at least a portion of a first spectrum of light emitted by said backlight source and emits light having a second spectrum different from said first spectrum.
- [c3] 3. The phosphor composition according to claim 2, wherein said second spectrum has higher intensity in regions having wavelengths of about 440–460 nm, about 550–570 nm, and about 630–680 nm than in at least another region of visible spectrum.
- [c4] 4. The phosphor composition according to claim 1, wherein said phosphor

composition comprises  $(\text{Sr}_{0.79} \text{Eu}_{0.1} \text{Mn}_{0.1} \text{Mg}_{0.11})_2 \text{P}_2 \text{O}_7$ ;  
 $(\text{Sr,Ca,Ba,Mg})_{10} (\text{PO}_4)_6 (\text{F,Cl,Br,OH})\text{:Eu}^{2+}$ ; and  $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2$ ;  
 $\text{Mn}^{4+}$ .

[c5] 5.The phosphor composition according to claim 1, wherein said phosphor composition comprises  $(\text{Ca,Sr,Ba})_8 (\text{Mg,Zn})(\text{SiO}_4)_4 (\text{Cl,F})_2 \text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  
 $(\text{Sr,Ca,Ba,Mg})_{10} (\text{PO}_4)_6 (\text{F,Cl,Br,OH})\text{:Eu}^{2+}$ ; and  $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2$ ;  
 $\text{Mn}^{4+}$ .

[c6] 6.A backlighting system for an LCD comprising:  
 a backlight source emitting light having a first spectrum at least in a range from about 300 nm to about 450 nm;  
 and a phosphor composition comprising at least a phosphor emitting blue light, at least a phosphor emitting green light, and at least a phosphor emitting red light; wherein said at least a phosphor emitting blue light is selected from the group consisting of  $(\text{Sr,Ca,Ba,Mg})_{10} (\text{PO}_4)_6 (\text{F,Cl,Br,OH})\text{:Eu}^{2+}$ ;  $(\text{Ba,Sr,Ca})\text{MgAl}_{10} \text{O}_{17} \text{:Eu}^{2+}$ ;  $(\text{Sr,Ca})_{10} (\text{PO}_4)_6 \cdot n\text{B}_2 \text{O}_3 \text{:Eu}^{2+}$ , wherein  $0 < n < 1$ ;  $2\text{SrO} \cdot 0.84\text{P}_2 \text{O}_5 \cdot 0.16\text{B}_2 \text{O}_3 \text{:Eu}^{2+}$ ;  $\text{Sr}_2 \text{Si}_3 \text{O}_8 \cdot 2\text{SrCl}_2 \text{:Eu}^{2+}$ ;  $\text{Ba}_3 \text{MgSi}_2 \text{O}_8 \text{:Eu}^{2+}$ ;  $\text{Sr}_4 \text{Al}_{14} \text{O}_{25} \text{:Eu}^{2+}$ ;  $\text{BaAl}_8 \text{O}_{13} \text{:Eu}^{2+}$ ; and mixtures thereof; said at least a phosphor emitting green light is selected from the group consisting of  $(\text{Ba,Sr,Ca})\text{MgAl}_{10} \text{O}_{17} \text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{Ba,Sr,Ca})\text{Al}_2 \text{O}_4 \text{:Eu}^{2+}$ ;  $(\text{Y,Gd,Lu,Sc,La})\text{BO}_3 \text{:Ce}^{3+}, \text{Tb}^{3+}$ ;  $(\text{Ba,Sr,Ca})_2 \text{SiO}_4 \text{:Eu}^{2+}$ ;  $(\text{Ba,Sr,Ca})_2 (\text{Mg,Zn})\text{Si}_2 \text{O}_7 \text{:Eu}^{2+}$ ;  $(\text{Sr,Ca,Ba})(\text{Al,Ga,In})_2 \text{S}_4 \text{:Eu}^{2+}$ ;  $(\text{Y,Gd,Tb,La,Sm,Pr,Lu})_x (\text{Al,Ga})_y \text{O}_{12} \text{:Ce}^{3+}$ , wherein  $x$  is in the range from about 2.8 to and including 3, and  $y$  is in the range from about 4.9 to about 5.1;  
 $(\text{Sr,Ca,Ba,Mg,Zn})_2 \text{P}_2 \text{O}_7 \text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{Ca,Sr,Ba,Mg})_{10} (\text{PO}_4)_6 (\text{F,Cl,Br,OH})\text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{Ca,Sr,Ba})_8 (\text{Mg,Zn})(\text{SiO}_4)_4 (\text{Cl,F})_2 \text{:Eu}^{2+}, \text{Mn}^{2+}$ ; and mixtures thereof; and said at least a phosphor emitting red light is selected from the group consisting of  $(\text{Gd,Y,Lu,La})_2 \text{O}_3 \text{:Eu}^{3+}, \text{Bi}^{3+}$ ;  $(\text{Gd,Y,Lu,La})_2 \text{O}_3 \text{:Eu}^{3+}, \text{Bi}^{3+}$ ;  $(\text{Gd,Y,Lu,La})\text{VO}_4 \text{:Eu}^{3+}, \text{Bi}^{3+}$ ;  $\text{SrS:Eu}^{2+}$ ;  $\text{SrY}_2 \text{S}_4 \text{:Eu}^{2+}$ ;  $\text{CaLa}_2 \text{S}_4 \text{:Ce}^{3+}$ ;  $(\text{Ca,Sr})\text{S:Eu}^{2+}$ ;  $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2$ ;  $\text{Mn}^{4+}$ ;  $(\text{Ba,Sr,Ca})\text{MgP}_2 \text{O}_7 \text{:Eu}^{2+}, \text{Mn}^{2+}$ ; and mixtures thereof; wherein said phosphor composition is disposed to absorb light of at least a portion of said first spectrum and emits light having a second spectrum different from said

first spectrum.

- [c7] 7.The backlighting system according to claim 6, wherein said second spectrum has higher intensity in regions having wavelengths of about 440–460 nm, about 550–570 nm, and about 630–680 nm than in at least another region of visible spectrum.
- [c8] 8.The backlighting system according to claim 6, wherein said phosphor composition comprises  $(\text{Sr}_{0.79} \text{Eu}_{0.1} \text{Mn}_{0.1} \text{Mg}_{0.11})_2 \text{P}_2 \text{O}_7$ ;  $(\text{Sr,Ca,Ba,Mg})_{10} (\text{PO}_4)_6 (\text{F,Cl,Br,OH})\text{:Eu}^{2+}$ ; and  $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2 \cdot \text{Mn}^{4+}$ .
- [c9] 9.The backlighting system according to claim 6, wherein said phosphor composition comprises  $(\text{Ca,Sr,Ba})_8 (\text{Mg,Zn})(\text{SiO}_4)_4 (\text{Cl,F})_2 \text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{Sr,Ca,Ba,Mg})_{10} (\text{PO}_4)_6 (\text{F,Cl,Br,OH})\text{:Eu}^{2+}$ ; and  $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2 \cdot \text{Mn}^{4+}$ .
- [c10] 10.The backlighting system according to claim 6, wherein said phosphor composition is dispersed in a substantially transparent resin to form a mixture, and said mixture is formed into a light-conversion layer that is disposed between said backlight source and a layer of liquid crystal material of said LCD.
- [c11] 11.The backlighting system according to claim 10, wherein said substantially transparent resin comprises at least a material selected from the group consisting of acrylate resins, epoxy resins, silicone, and silicone-functionalized epoxy.
- [c12] 12.The backlighting system according to claim 10, wherein said mixture further comprises particles of a light-scattering material.
- [c13] 13.The backlighting system according to claim 6, wherein said backlight source comprises at least a light-emitting diode ("LED").
- [c14] 14.The backlighting system according to claim 13, wherein said mixture is disposed on a light-emitting element of said LED.
- [c15] 15.The backlighting system according to claim 6, wherein said backlight source

comprises at least an organic electroluminescent device ("OLED").

[c16] 16. The backlighting system according to claim 15, wherein said OLED comprises an organic light-emitting layer disposed between two electrodes, and said organic light-emitting layer emits light when a voltage is applied across said electrodes.

[c17] 17. A liquid crystal display comprising:

(a) a backlighting system comprising:

(1) a backlight source emitting light having a first spectrum at least in a range from about 300 nm to about 450 nm; and

(2) a phosphor composition comprising at least a phosphor emitting blue light, at least a phosphor emitting green light, and at least a phosphor emitting red light; wherein said at least a phosphor emitting blue light is selected from the

group consisting of  $(\text{Sr,Ca,Ba,Mg})_{10}(\text{PO}_4)_6(\text{F,Cl,Br,OH})\text{:Eu}^{2+}$ ;  $(\text{Ba,Sr,Ca})\text{MgAl}_{10}\text{O}_{17}\text{:Eu}^{2+}$ ;  $(\text{Sr,Ca})_{10}(\text{PO}_4)_6\text{nB}_2\text{O}_3\text{:Eu}^{2+}$ , wherein  $0 < n < 1$ ;  $2\text{SrO} \cdot 0.84\text{P}_2\text{O}_5 \cdot 0.16\text{B}_2\text{O}_3\text{:Eu}^{2+}$ ;  $\text{Sr}_2\text{Si}_3\text{O}_8 \cdot 2\text{SrCl}_2\text{:Eu}^{2+}$ ;  $\text{Ba}_3\text{MgSi}_2\text{O}_8\text{:Eu}^{2+}$ ;  $\text{Sr}_4\text{Al}_{14}\text{O}_{25}\text{:Eu}^{2+}$ ;  $\text{BaAl}_8\text{O}_{13}\text{:Eu}^{2+}$ ; and mixtures thereof; said at least a phosphor emitting green light is selected from

the group consisting of  $(\text{Ba,Sr,Ca})\text{MgAl}_{10}\text{O}_{17}\text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{Ba,Sr,Ca})\text{Al}_2\text{O}_4\text{:Eu}^{2+}$ ;  $(\text{Y,Gd,Lu,Sc,La})\text{BO}_3\text{:Ce}^{3+}, \text{Tb}^{3+}$ ;  $(\text{Ba,Sr,Ca})_2\text{SiO}_4\text{:Eu}^{2+}$ ;  $(\text{Ba,Sr,Ca})_2(\text{Mg,Zn})\text{Si}_2\text{O}_7\text{:Eu}^{2+}$ ;  $(\text{Sr,Ca,Ba})(\text{Al,Ga,In})_2\text{S}_4\text{:Eu}^{2+}$ ;  $(\text{Y,Gd,Tb,La,Sm,Pr,Lu})_x(\text{Al,Ga,In})_y\text{O}_{12}\text{:Ce}^{3+}$ , wherein  $x$  is in the range from about 2.8 to and including 3, and  $y$  is in the range from about 4.9 to about 5.1;

$(\text{Sr,Ca,Ba,Mg,Zn})_2\text{P}_2\text{O}_7\text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{Ca,Sr,Ba,Mg})_{10}(\text{PO}_4)_6\text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{F,Cl,Br,OH})\text{:Eu}^{2+}, \text{Mn}^{2+}$ ;  $(\text{Ca,Sr,Ba})_8(\text{Mg,Zn})(\text{SiO}_4)_4(\text{Cl,F})_2\text{:Eu}^{2+}, \text{Mn}^{2+}$ ; and mixtures thereof; and said at least a phosphor emitting red light is selected from the group consisting of  $(\text{Gd,Y,Lu,La})_2\text{O}_3\text{:Eu}^{3+}, \text{Bi}^{3+}$ ;  $(\text{Gd,Y,Lu,La})_2\text{O}_3\text{S}\text{:Eu}^{3+}, \text{Bi}^{3+}$ ;  $(\text{Gd,Y,Lu,La})\text{VO}_4\text{:Eu}^{3+}, \text{Bi}^{3+}$ ;  $\text{SrS}\text{:Eu}^{2+}$ ;  $\text{SrY}_2\text{S}_4\text{:Eu}^{2+}$ ;  $\text{CaLa}_2\text{S}_4\text{:Ce}^{3+}$ ;  $(\text{Ca,Sr})\text{S}\text{:Eu}^{2+}$ ;  $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2\text{:Mn}^{2+}$ ;  $(\text{Ba,Sr,Ca})\text{MgP}_2\text{O}_7\text{:Eu}^{2+}, \text{Mn}^{2+}$ ; and mixtures thereof; wherein said phosphor composition is disposed to absorb light of at least a portion of said first spectrum and emits light having a second spectrum different from said first spectrum; and

(b) a liquid crystal material disposed to receive light having said second spectrum.

[c18] 18. The liquid crystal display according to claim 17; wherein said liquid crystal material is disposed between a pair of first and second substantially transparent plates, a surface of each of said plates adjacent to said liquid crystal material carries an electrode such that overlapping regions of two electrodes define a plurality of pixels of said liquid crystal display; and color filters allowing blue, green, and red light to pass through said liquid crystal material are disposed on every three adjacent pixels.

[c19] 19. The liquid crystal display according to claim 17, wherein said second spectrum has higher intensity in regions having wavelengths of about 440–460 nm, about 550–570 nm, and about 630–680 nm than in at least another region of visible spectrum.

[c20] 20. The liquid crystal display according to claim 17, wherein said phosphor composition comprises  $(\text{Sr}_{0.79}\text{Eu}_{0.1}\text{Mn}_{0.1}\text{Mg}_{0.11})_2\text{P}_2\text{O}_7$ ;  $(\text{Sr,Ca,Ba,Mg})_{10}(\text{PO}_4)_6(\text{F,Cl,Br,OH})\text{:Eu}^{2+}$ ; and  $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2\text{:Mn}^{4+}$ .

[c21] 21. The liquid crystal display according to claim 17, wherein said phosphor composition comprises  $(\text{Ca,Sr,Ba})_8(\text{Mg,Zn})(\text{SiO}_4)_4(\text{Cl,F})_2\text{:Eu}^{2+},\text{Mn}^{2+}$ ;  $(\text{Sr,Ca,Ba,Mg})_{10}(\text{PO}_4)_6(\text{F,Cl,Br,OH})\text{:Eu}^{2+}$ ; and  $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2\text{:Mn}^{4+}$ .

[c22] 22. The liquid crystal display according to claim 17, wherein said phosphor composition is dispersed in a substantially transparent resin to form a mixture, and said mixture is formed into a light-conversion layer that is disposed between said backlight source and a layer of liquid crystal material of said LCD.

[c23] 23. The liquid crystal display according to claim 22, wherein said substantially transparent resin comprises at least a material selected from the group consisting of acrylate resins, epoxy resins, silicone, and silicone-functionalized epoxy.

- [c24]        24.The liquid crystal display according to claim 22, wherein said mixture further comprises particles of a light-scattering material.
- [c25]        25.The liquid crystal display according to claim 17, wherein said backlight source comprises at least an LED.
- [c26]        26.The liquid crystal display according to claim 25, wherein said mixture is disposed on a light-emitting element of said LED.
- [c27]        27.The liquid crystal display according to claim 17, wherein said backlight source comprises at least an OLED.
- [c28]        28.The liquid crystal display according to claim 27, wherein said OLED comprises an organic light-emitting layer disposed between two electrodes, and said organic light-emitting layer emits light when a voltage is applied across said electrodes.